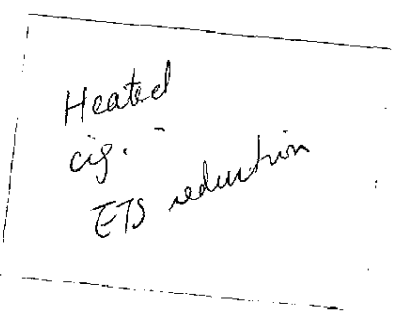
PRESENT AND FUTURE OF INDOOR AIR QUALITY

Proceedings of the Brussels Conference,
14–16 February 1989

Editors:

C.J. Bieva, Y. Courtois and M. Govaerts



1989

EXCERPTA MEDICA, Amsterdam – New York – Oxford

International Congress Series No. 860
ISBN 0 444 81134 6

This book is printed on acid-free paper.

Published by:
Elsevier Science Publishers B.V.
(Biomedical Division)
P.O. Box 211
1000 AE Amsterdam
The Netherlands

Sole distributors for the USA and Canada:
Elsevier Science Publishing Company Inc.
655 Avenue of the Americas
New York, NY 10010
USA

Printed in The Netherlands

FOREWORD

Indoor air quality conservation and procedures for the measurement of related potential pollutants, such as radon, asbestos, gases, pesticides, tobacco smoke and bacteria from air conditioning systems, have seen important changes in recent years, while the range and the scope of the studies have continued to expand.

In addition to helping preserve public health, the field of interest is now extending to include such areas as architectural design, ventilation engineering, sociology, psychology and legal aspects. Related analytical techniques like gas chromatography and mass spectroscopy have undergone parallel refinements and their range of application has broadened.

These advances were discussed at the Conference 'Present and Future of Indoor Air Quality', held in Brussels, February, 1989, following symposia on indoor air quality at Essen and Tokyo in 1987 and London in 1988. The sessions were attended by about 200 scientists representing 20 countries. A total of 92 papers and posters were presented covering such topics as pathogenesis and epidemiology, sources of indoor air contamination and risk assessment, chemistry of indoor air related to the outdoor air quality, social and psychological aspects of poor indoor air quality, motivation and attitudes, future guidelines for the improvement of indoor air quality through architectural and ventilation design, and air quality monitoring.

The proceedings include full texts and posters presented during the meeting. The organising committee hopes that they will constitute a useful guide for the improvement of our indoor air quality in the future.

CONTENTS

OPENING SESSION: RISK ASSESSMENT AND HEALTH

SECTION 1: ETS AND PASSIVE SMOKING

SECTION 2: INDOOR AIR QUALITY: CHEMISTRY AND BIOLOGICAL EFFECTS

SECTION 3: INDOOR AIR QUALITY: VENTILATION, CLIMATISATION AND POLLUTANTS

© 1989 Elsevier Science Publishers B.V. (Biomedical Division)
Present and future of indoor air quality.
C.J. Bieva, Y. Courtois, M. Govaerts, editors.

NICOTINE ABSORPTION IN HUMANS FOLLOWING EXPOSURE TO ENVIRONMENTAL TOBACCO SMOKE GENERATED FROM DIFFERENT TYPES OF CIGARETTES

J. D. DEBETHIZY, L. E. BATES, R. A. DAVIS, D. L. HEAVNER, P. R. NELSON, J. C. WALKER, and J. H. ROBINSON

Biochemical and Biobehavioral R&D. Bowman Gray Technical Center. R. J. Reynolds Tobacco Co., Winston-Salem, NC 27102

INTRODUCTION

Environmental tobacco smoke (ETS) is the aged and diluted smoke present in the atmosphere as a result of people smoking. ETS originates from two sources: the smoke exhaled by the smoker and the sidestream smoke produced by the cigarette during the interval between puffs. The effect of ETS on indoor air quality (1) and on the health of passive smokers (2,3) is a topic of current interest. Recently, a new cigarette has been developed which heats rather than burns tobacco (4). The reduction of ETS was one of the developmental objectives for this cigarette.

To determine whether this goal was achieved, nonsmokers were exposed in an environmental chamber to ETS from this new cigarette and from tobacco-burning cigarettes. Nicotine has been proposed as a marker for ETS exposure (5). Exposure of nonsmokers to ETS was estimated by continuous measurement of nicotine in the chamber atmosphere, calculation of the quantity of nicotine inhaled by each individual, and by measurement of urinary and salivary nicotine and cotinine. Since very few studies have been conducted where inhalation of specific components of ETS has been accurately quantified in nonsmokers (5), the relationship between the concentration of nicotine and cotinine in saliva and urine and exposure to nicotine derived from ETS was examined.

METHODS

Environmental Chamber

The environmental chamber used for this study has been described previously (6). The chamber is an 18-cubic meter room with stainless steel walls. The room was operated in the conditioned makeup mode--building air was cooled and dehumidified to regulate temperature/humidity conditions in the chamber. The air exchange rate was maintained at six air changes per hour. The room air was characterized by measuring carbon monoxide, oxides of nitrogen, total volatile organic compounds, nicotine, particle number concentration, and particle mass concentration in real-time as described by Nelson et al. (this volume). Concentrations of respirable suspended particles (RSP), nicotine and selected carbonyls

were determined as time weighted average concentrations over the ETS exposure period (Nelson et al., this volume).

ETS Exposure

Two pairs of smokers were used to generate the ETS in the chamber. The first pair of smokers entered the chamber before the start of the session. They smoked one cigarette each at 12, 24, 36, and 48 minutes into the session. Following their fourth smoking interval, the first pair of smokers left the chamber, and a second pair of smokers entered and smoked one cigarette each at 60, 72, 84, and 96 minutes. The second pair of smokers remained in the chamber until the conclusion of the experiment. A total of 16 cigarettes were smoked by the two pairs of smokers. The cigarettes used in the study were the Kentucky 1R4F (1R4F), an ultra-low tar brand (ULT), and a cigarette that heats rather than burns tobacco (NEW).

Pilot Study

The objectives of the pilot study were to determine if smoking 16 cigarettes in an 18-cubic meter chamber over 120 minutes would generate sufficient ETS to detect changes in the concentration of nicotine and cotinine in body fluids and blood carboxyhemoglobin. In addition, the study was designed to determine if mouth rinsing prior to collection of saliva was necessary for accurate determination of salivary concentrations of nicotine. Four male nonsmokers were exposed to ETS generated from two smokers who smoked a total of sixteen 1R4F cigarettes as described above. Each nonsmoker participated in two sessions separated by a week, one in which he water-rinsed his mouth prior to saliva collection, and one in which there was no rinse. Two subjects were exposed to ETS in each session which lasted 120 minutes.

Comparative Study

Eleven male, nonsmokers were exposed in the environmental chamber (see figure 1 of Walker et al., this volume) to four conditions on four different occasions separated by a week using a counterbalanced, repeated measures design as illustrated in Table 1.

The four conditions were ETS from 1R4F, ULT, and NEW cigarettes and a nonsmoking control where everything was identical to the smoking conditions except the cigarettes were not lit (CONTROL). Subjects were asked to avoid exposure to ETS to minimize exposure to nicotine, and consumption of solanaceous vegetables was recorded. To control short-term effects of diet on the composition of saliva and salivary flow rate and on the pH of urine, meals were provided on the test day and were the same each time an individual tested.

Table 1
Testing Schedule for the 11 Subjects Participating in the Repeated Measures Design

No. of Subjects	Condition Order			
	Week 1	Week 2	Week 3	Week 4
2	1R4F	NEW	CONTROL	ULT
2	ULT	CONTROL	1R4F	NEW
2	NEW	1R4F	ULT	CONTROL
2	CONTROL	ULT	NEW	1R4F
2	1R4F	CONTROL	NEW	ULT
1	ULT	NEW	CONTROL	1R4F

Urine was collected for 24 hours prior to testing and 6, 24, 48, and 72 hours after the start of each of the four conditions. Mixed saliva samples were collected 30 minutes prior to entering the chamber, six minutes after entering the chamber but before generation of the ETS and at selected times during and after the ETS exposure. Salivary flow was stimulated by chewing 5 cm squares of Parafilm® for 30 seconds, and the saliva was expectorated into a screw-cap tube. This was repeated three times, providing approximately 3 ml of mixed saliva. Twenty ml of distilled water was used for the the mouth rinse. The rinse water was recovered and analyzed for nicotine and cotinine. Preliminary studies indicated that if the sample collection tubes were opened only long enough to collect the samples (approximately five seconds), then negligible contamination of the saliva occurred from nicotine present in the ETS.

The total amount of ETS-nicotine inhaled by each subject each time they appeared was calculated as follows:

$$\text{Total Inhaled Nicotine } (\mu g) = \left[\begin{array}{c}\text{Chamber} \\ \text{Concentration} \\ (\mu g/\text{liter})\end{array}\right] \left[\begin{array}{c}\text{Minute} \\ \text{Ventilation} \\ (\text{liter/min})\end{array}\right] \left[\begin{array}{c}\text{Exposure} \\ \text{Time} \\ (\text{min})\end{array}\right]$$

Minute ventilation was determined using the Respitrace System. Each subject's perception of the ETS in the chamber was assessed using a visual analog scale ballot the results of which are presented in this volume (Walker et al.).

Biological Fluid Measurements

Salivary and urinary nicotine and cotinine were assayed using gas chromatography equipped with nitrogen specific detection (limit of detection 1 and 4

ng/ml, respectively). To achieve greater sensitivity for cotinine in urine and saliva samples collected when the subjects were not exposed to ETS, samples were assayed by GC with mass selective detection (limit of detection 0.8 ng/ml).

RESULTS

Pilot Study

The concentration of nicotine in the saliva of the nonsmokers tracked the rise and fall of ETS generated by the two smokers (Figure 1).

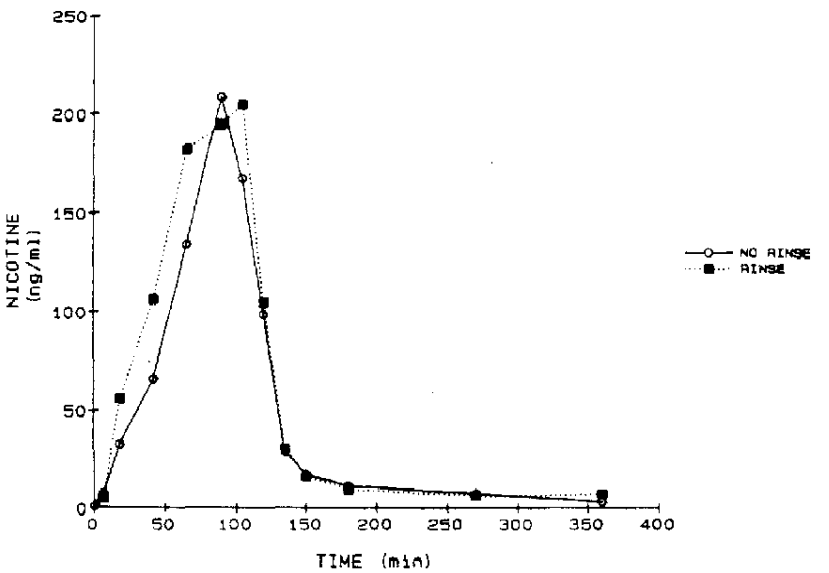


Figure 1. Salivary nicotine in four nonsmokers exposed to ETS from sixteen 1R4F cigarettes on two occasions separated by a week: Once with mouth rinsing prior to saliva collection and once without mouth rinsing.

Salivary nicotine returned to baseline within two hours after the subjects left the ETS chamber. As shown in Figure 1, there was no effect of mouth rinsing on salivary nicotine. In addition, urinary nicotine and cotinine were elevated by the concentrations of ETS generated by the smoking regimen (data not shown). Therefore, we concluded that exposure of nonsmokers to ETS generated by smoking 16 cigarettes over two hours produces sufficient changes in salivary and urinary nicotine and urinary cotinine to permit comparisons of cigarettes that yield different amounts of sidestream smoke. Blood carboxyhemoglobin and plasma nicotine and cotinine were not altered by this exposure regimen and therefore were not used in the comparison study. Rinsing the mouth with water prior to

saliva collection was not necessary for measuring salivary nicotine and therefore not performed in the subsequent study.

Comparative Study

The area under the salivary nicotine versus time curve (AUC) was 6- to 7.5-fold less when the subjects were exposed to ETS from the cigarette that heats tobacco compared to either cigarette that burns tobacco (ULT and 1R4F; Figure 2).

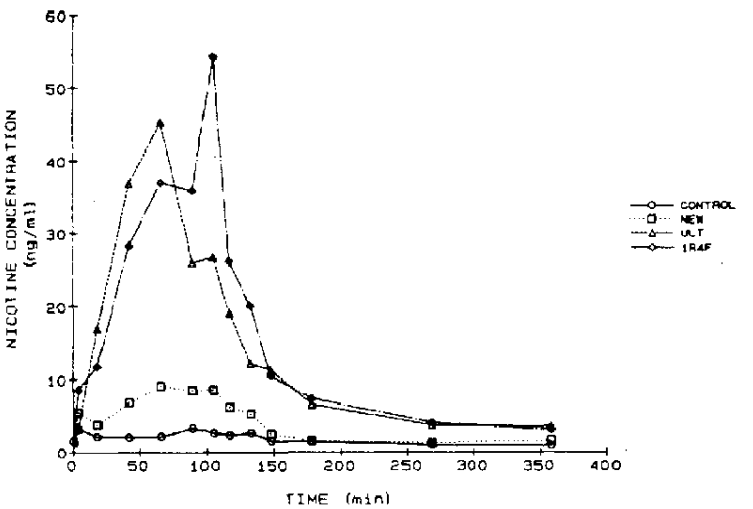


Figure 2. Salivary nicotine in 11 nonsmokers following exposure to ETS from NEW, ULT, 1R4F, or CONTROL.

Peak salivary nicotine was 45 to 55 ng/ml when subjects were exposed to peak concentrations of ETS nicotine of 200 to 250 μg/cubic meter from 1R4F and ULT and 8 ng/ml when subjects were exposed to peak concentrations of ETS nicotine of 40 μg/cubic meter from the cigarette that heats tobacco (NEW; Figure 3). Nicotine exposures from ETS as high as 250 μg/cubic meter did not produce significant changes in salivary cotinine above baseline (data not shown). These data indicate that salivary cotinine is not a sensitive measure for quantifying short-term ETS exposures.

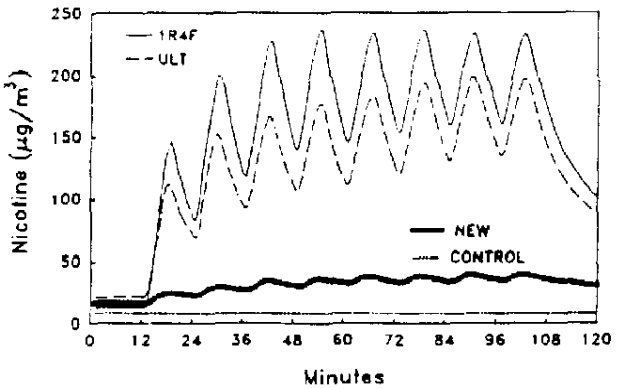


Figure 3. Concentration of nicotine in ETS chamber measured in real-time by mass spectrometry while 16 cigarettes (NEW, ULT, or 1R4F) were smoked or during the nonsmoking control (CONTROL).

Peak urinary nicotine excretion occurred between 6 and 24 hours (Figure 4A) while peak urinary cotinine excretion occurred between 24 and 48 hours after the start of the ETS exposure (Figure 4B). The total amount of nicotine excreted in the urine was 3-fold to 4-fold less following exposure to ETS from the cigarette that heats tobacco than to ETS from the cigarettes that burn tobacco (Figure 4A). The total amount of cotinine excreted in the urine was 5-fold to 7-fold less following exposure to ETS from the cigarette that heats tobacco than to ETS from the cigarettes that burn tobacco (Figure 4B).

The concentration of nicotine in the chamber air tracked the number of cigarettes being smoked in the chamber as shown in Figure 3. This real-time measure of nicotine was used along with measurements of the total volume of air inhaled to calculate the total amount of nicotine inhaled by each subject. The amount of nicotine inhaled by each subject each time they appeared was correlated more closely with the amount of cotinine excreted in the urine [multiple R = 0.67 (Figure 5)] than with the amount of nicotine (0.44) or nicotine plus cotinine (0.54) excreted in the urine.

The correlation of salivary nicotine AUC and inhaled nicotine was 0.46. The linear regression equation relating the amount of nicotine inhaled from ETS to the amount of cotinine excreted in the urine was:

$$\text{amount nicotine inhaled } (\mu g) = (6.01) * \text{amount of cotinine excreted in 72 hr } (\mu g) - 6.40$$

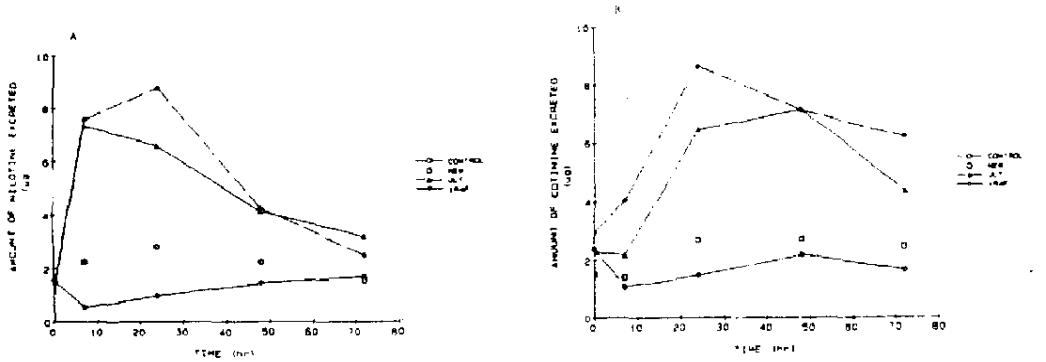


Figure 4. Urinary nicotine (A) and cotinine (B) in 11 nonsmokers following exposure to ETS from NEW, ULT, IR4F, or CONTROL.

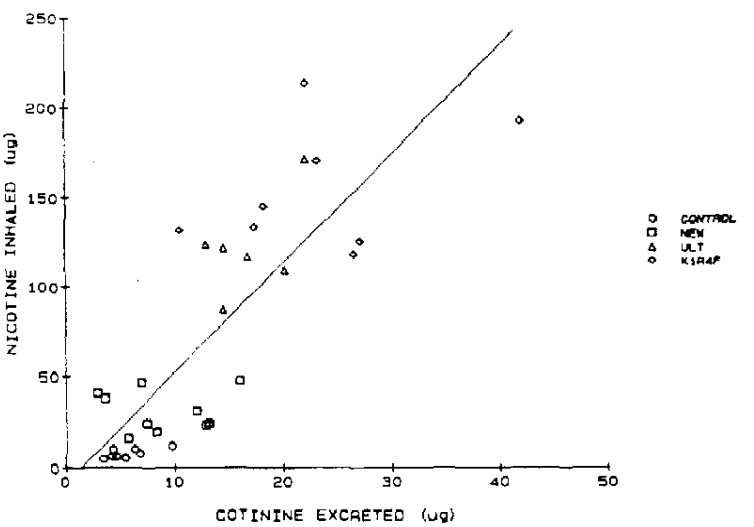


Figure 5. Correlation of the amount of cotinine excreted with the amount of nicotine inhaled from ETS by 11 nonsmokers tested on four occasions.

CONCLUSIONS

1. Salivary nicotine and urinary nicotine and cotinine were useful measures for comparing short-term exposure of nonsmokers to ETS from different cigarettes under controlled conditions.

2. Exposure to ETS from the cigarette that heats tobacco (NEW) produced small increases in the concentration of nicotine and cotinine in urine and saliva over background (exposure to clean air) while exposure to ETS from an equal number of tobacco burning cigarettes (ULT and IR4F) resulted in exposures which were 5- to 7.5-fold higher.

3. The reductions in specific ETS components achieved with the NEW cigarette (See Nelson et al., this volume) corresponded with reduced exposure of nonsmokers to ETS as judged by salivary nicotine and urinary nicotine and cotinine.

ACKNOWLEDGMENTS

The authors would like to thank P.O. McKaig, S.W. Ingram, and J.M. Greene for excellent technical assistance and O.R. Montgomery for typing this manuscript.

REFERENCES

1. Perry, R and Kirk PW (1988). Indoor and Ambient Air Quality. Selper Publications, London.

2. Committee on Passive Smoking, Board of Environmental Studies and Toxicology, National Research Council (1986). Environmental Tobacco Smoke-- Measuring Exposures and Assessing Health Effects. National Academy Press, Washington, DC.

3. U.S. Department of Health and Human Services (1986). The Health Consequences of Involuntary Smoking. Rockville, MD.

4. R. J. Reynolds Tobacco Company (1988). Chemical and Biological Studies on New Cigarette Prototypes That Heat Instead of Burn Tobacco. R. J. Reynolds Tobacco Co., Winston-Salem, NC.

5. Haley NJ, Sepkovic DW, Brunnemann KD, and Hoffmann D. (1988). Biomarkers for Assessing Environmental Tobacco Smoke Uptake. Presented at the International Specialty Conference on Combustion Processes and the Quality of the Indoor Environment, Niagra Falls, NY.

6. Heavner DL, Thome FA, Eudy LE, Ingegrethsen BJ, and Green CR (1986). A Test Chamber and Instrumentation for the Analysis of Selected Environmental Tobacco Smoke (ETS) Components. Proceedings of the 79th Air Pollution Control Association, 86-37.9.